The Air Line Pilot

June, 1957

ALPA

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The Vanguard

Shown on author's F-84-F's instrument panel: control panel for the Doppler (Radan) on upper left; Ground Speed and Drift Indicator on upper right.

Antenna installation in bottom of F-84, including transmitter and receiver.

Doppler And Inertial Navigation

An Air Line Pilot And Air Force Consultant Explains Two Navigation Principles About Which Pilots Are Going To Be Hearing More And More

By Capt. Charles Blair
PAA

In the next few years we air line pilots are going to hear a lot about Doppler navigation as we phase into the new jet transports. Later on we may be toying with inertial navigation. Perhaps an explanation of the theory of Doppler and inertial navigation might be in order.

Doppler navigation is a dead reckoning technique. The primary function of Doppler-radar is the measurement of ground speed and drift angle over all types of terrain, including open water.

Doppler Effect—What It Measures

The Doppler effect is the phenomenon of the change of frequency of a propagated wave when there is a relative motion between the source and the observer. A familiar example of the Doppler effect is the case of the sound of the whistle of a train, which is moving toward a stationary observer. As the train approaches, the observer hears a fairly steady pitch which is higher than the true pitch. It drops quickly as the train passes to a frequency below the true pitch, and remains approximately at the lower value as the train moves away from the observer. The wave length of the sound wave moving ahead of the train is compressed slightly because the whistle is moving forward as it emits the sound, and the speed of sound travel remains unchanged (it is determined only by the propagating medium, air, in this case). The shortened wave length, therefore, results in a higher sound frequency heard by the observer as the train moves toward him. The same reasoning explains why the frequency, or pitch, drops when the train passes and moves away from the observer. In

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this case the whistle is moving away along the direction of propagation. The wave length is slightly expanded, resulting in a lower frequency or pitch.

The Doppler frequency shift is proportional to the rate of change of the propagation path, and hence to the component of relative velocity of source and observer along the line between them.

The Airborne System

In an airborne Doppler-radar system the energy is emitted by a moving transmitter, and reflected by the stationary ground back to a receiver in the aircraft. The signal beamed forward and down undergoes a Doppler shift and is at a higher frequency as it strikes the ground than the original radar transmission frequency, analogous to the case of the moving train whistle and the stationary observer. The energy is reflected at the new frequency by the earth which may be considered a new transmitter. The receiver in the aircraft is moving relative to the earth, and the received signal undergoes another Doppler shift upward in frequency.

Changes of ground speed, of course, bring about changes of frequency. These changes are interpreted in a computer and displayed on a ground speed indicator.

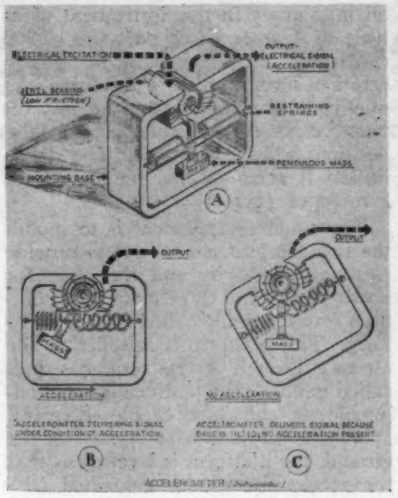
Ground speed is found as the vector sum of the horizontal speed components. Drift angle is found as the angle between the ground velocity and the aircraft heading, being obtained from velocity measurements perpendicular to the heading of the aircraft. Drift angle is thus continuously displayed along with ground speed.

This ground speed and drift information can be fed into a dead reckoning memory computer, which continuously displays: 1) wind direction and velocity; 2) present position in latitude and longitude; 3) course and distance to the next check point, destination, or alternate destination, whichever is desired.

Proven Doppler installations are now available in lightweight compact units, adaptable to commercial transport aircraft.

Inertial Navigation

Inertial navigation is also a type of dead-reckoning technique; this means that if both the coordinates of the starting point and the direction of North are known at takeoff, the inertial navigation system will automatically measure the distance travelled east-west and north-south, and will continuously keep track of the vehicle's latitude and longitude during the trip. It does this



Accelerometer (schematic)

without requiring the assistance of external optical, magnetic or radio information; it operates solely on the basis of measuring the vehicle's acceleration during its travel.

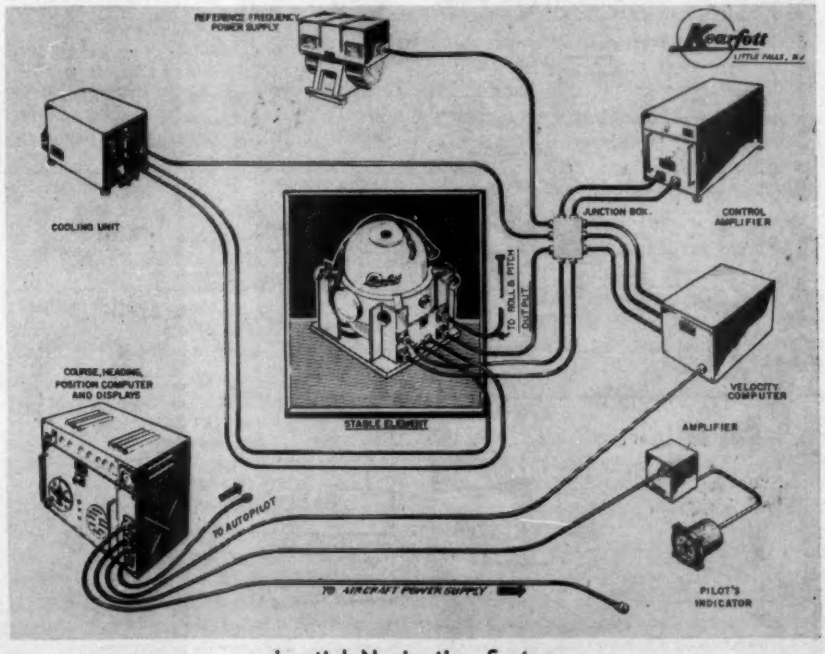
The inertia of a vehicle represents its resistance to a change of its speed. Acceleration is the quantity which denotes the rate of change of speed; its magnitude indicates the effect that a given motive force has upon a given mass (or inertia). Thus, an airplane starting at rest and achieving a speed of 1000 m.p.h. after a half hour, has accelerated at a value of 1000 m.p.h. per half hour. Its *average* speed during the half hour was 500 m.p.h. and the total distance travelled was 250 miles (average speed times the duration of this speed).

The Accelerometer

The heart of the inertial navigation system is the accelerometer; this instrument is attached to the vehicle and measures the latter's acceleration (in the above instance, its electrical output would represent 1000 m.p.h. per half hour). The accelerometer's output is fed into an automatic computer where it is multiplied continuously by the *time* during which it is maintained and the resulting quantity, at any moment, is the *speed* of the vehicle (in the above case, the speed indicated would change, showing zero at the start, building up to 500 m.p.h. in 15 minutes, and reading 1000 m.p.h. in 30 minutes).

As the next step, the electrical output representing *speed* is multiplied automatically in the computer by the time during which *it* is maintained, and the result is a quantity representing the distance travelled. This value of distance, when computed both in an east-west and a north-south direction, is converted to the vehicle's present position, in terms of latitude and longitude.

An accelerometer is a type of pendulum—a small mass suspended from a wire or thin rod; sometimes the suspension member is restrained by a spring in order to control the swing of the mass. When the vehicle upon which this instrument is mounted is



Inertial Navigation System

either stationary or is traveling at a constant speed (not accelerated), no signal output is emitted; during acceleration, the suspended mass lags behind its point of suspension because of its inertia. An electrical signal proportional to the change of speed is delivered from the takeoff device. It is of great significance to note that the pendulous mass—and its suspension wire, when at rest, always are aligned along a line passing through the center of the earth, since it is attracted by the earth's gravity field. If the accelerometer is fastened to a base and the base is merely tilted but not accelerated, the suspended mass swings through the angle of tilt; in such a case, an output is transmitted from the instrument even though its base is *not* accelerated over the earth's surface.

The inability of the accelerometer to distinguish between a tilt of its mounting and an actual acceleration, leads to the necessity of *stabilizing* the base, so that after being initially set up in the true horizontal, it is kept from being tilted. In this manner, it is established that *any* accelerometer output represents actual acceleration and, thus, linear motion over the earth's surface, rather than tilt.

High Quality

The quality of accelerometers used for inertial navigation systems is high; an inaccuracy in this instrument of as little as two or three parts in 10,000 can result, in normal flight, in position errors of several miles. In addition, the quality of the stabilization against tilt must be equally accurate, or else false positions will be indicated. The stabilization is accomplished by the use of gyroscopes (gyros).

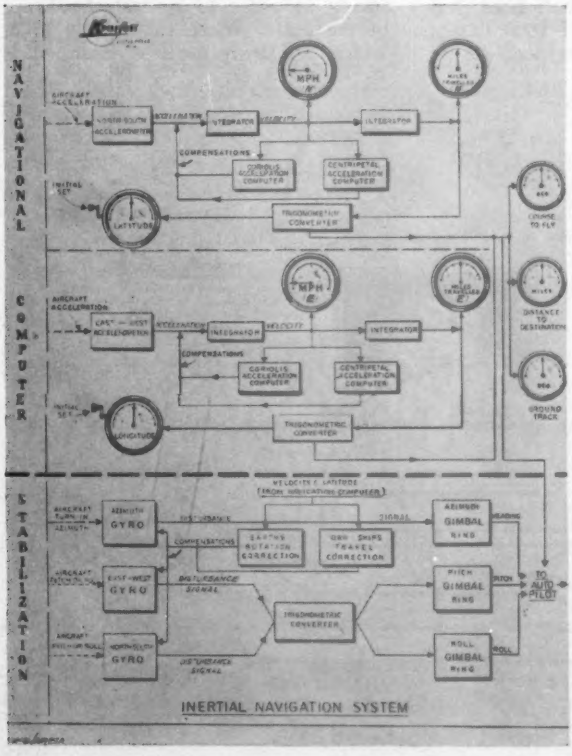
The usual arrangement is to mount the two accelerometers (one to provide east-west sensitivity and the other for north-south) and three gyros on a common frame, usually called a stable platform. This platform is attached to the aircraft through several rotatable rings called gimbals; the platform-gimbal ensemble is called a Stable Element. When the airplane is stationary on the ground, the platform is levelled so that the accelerometers are not tilted (deliver a zero signal); the speed and distance meters of the computer are set to read zero. In addition, the platform is lined up with reference to North. After takeoff, whenever the airplane tilts (rolls or pitches) or makes a turn, the gyros on the platform sense any rotation imparted to the platform; before the *platform* can turn, the gyros send appropriate electrical signals to small motors which are attached to the gimbal rings. These rings rotate just in step with the aircraft motions, but opposite in direction, and thus stabilize the platform, preventing it from tilting or turning away from its initial pretakeoff alignment. In this way, the outputs from the accelerometers truly represent the acceleration of the vehicle *along known directions.*

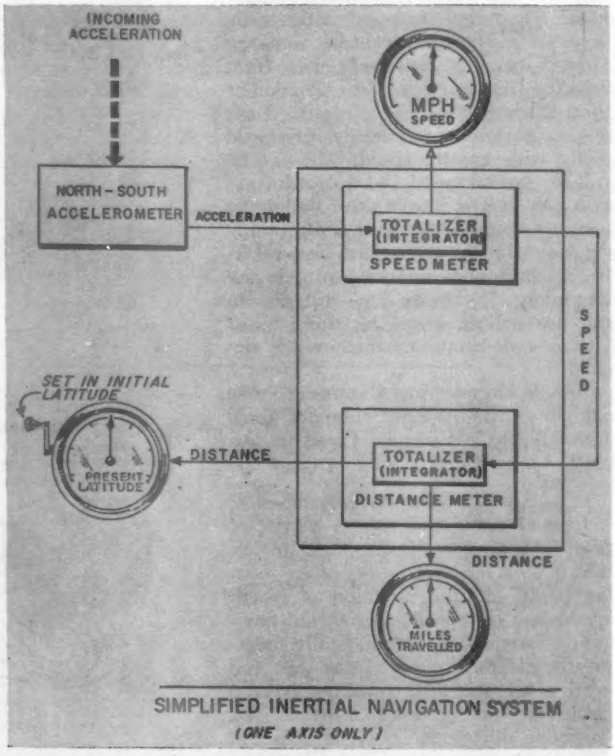
When the aircraft flies over the earth's surface at a constant altitude, it must be flying along a curved path in the vertical plane, matching the curvature of the earth. Since the platform's gyros would sense such a turning rate (although minute) and would try to keep the platform aligned in the original "level" attitude, the pendulum would shortly not be pointing to the center of the earth. The accelerometer would transmit a spurious signal. In order to avoid this, the platform must be continuously and deliberately turned at a rate which is exactly in step with the rate of curvature of the vehicle around the earth. The output of the speed meter is utilized in the computer to generate the proper signal to turn the platform; this is done by continuously applying a rotation to the gyros, which in turn rotate the gimbals.

Additional Corrections

There are several additional corrections which are generated within the system, the purpose of which are to maintain the original platform align-

(Continued on Page 23)





Some Thoughts On Responsibility

Text Of The ALPA Treasurer's Address To The Board Of Directors At The 14th Convention Which Is Being Printed In Response To Popular Request

By D. J. Smith
ALPA Treasurer

It hardly seems possible that two years have gone by since I last stood on this platform. Those two years have been full for me, very full. They have been devoted almost in their entirety to my job as Treasurer of this Association. With some 278 days spent in the Home Office, and at the same time flying a regular schedule of 60 to 70 hours per month, there has been little time left for other things. I have enjoyed it though, and think I have accomplished some things, and I would like to tell you about them. It is also my duty to give you an accounting of the funds that you have put in my charge.

I ask you to bear in mind that I am not a polished speaker. I have had no oratorical training, and I am not a proponent of the well-turned phrase. I am, on the other hand, a blunt speaker, and I like to talk directly and to the point.

Two Years Ago

Let's go back now and take a look at where we stood two years ago. We were then just emerging from what I call, for lack of a better word, the Behncke Sickness. We were running a terrific temperature, and we still show a few signs of that sickness in some quarters. You don't turn from a sickness such as that and immediately start walking the streets a well man or a well Association. Rebuilding has to take place, and rebuilding is slow. Nevertheless, we are building perhaps slowly, but more surely this time.

I recall to you that I made no campaign for the office that I now hold and no effort to obtain it. I was elected without a platform and with no commitments. I had made no statements prior to my election as to what I was going to do or what my plans would be. I had, when I took office, only one known asset and that was a reputation for honesty, fair play and hard work on my own air line. I was, after my election, asked to address the Convention at large, and during this address the question was asked from the floor, "What are you going to do?" I replied that I wasn't quite sure as yet, but the first thing that I was going to do was to go down and count the money and see if it was all there. I did just that. It was there—and I report to you now that it is still there and more with it. This Association's books have always been, and I hope always will be, spotless. That statement cannot be made by some of the labor organizations.

Increased Activities

I have just stated that our assets have increased. Two years ago our assets were $2,602,000. They are now $3,375,000. This rise did not, however, come about by the imposition of tighter economic controls on our central treasury. The opposite of that is true. In fact, I believe that in the last two years I have spent more of this Association's money than any previous Treasurer in the same amount of time.

How could this paradox of spending more money, yet having more left, come about? Well, first of all we have gained some members, and dues from the membership are the lifeblood of this Association. But this source of income is a minor one in comparison to the effort that has been made in other directions. We intensified our fight against dues delinquency in this Association. I abhor a member who fails to pay his dues unless he has good reason, and then I would like to be the first to come to his assistance. This Association was built to help the man in trouble.

We took a set of By-Laws with teeth in them, and we followed them. Our dues delinquency was two years ago running around 15%, partly due to the poor set of By-Laws we used to have and partly due to the temperature that we were running. That temperature has mostly gone away. There are a few sore spots still remaining, and those sore spots ought to be cleaned out before they infect the whole again.

Lowest Delinquency

The net result of this effort has been to decrease our delinquencies to less than 2.5% at the present moment, the lowest in our recent history. I forecast to you that by March 31 next, the end of the second quarter of this fiscal year, this figure will fall to 1% where it should stabilize.

We have also built our assets by paying closer attention to our investments. Right now we have $2,371,000 in investments at a ratio of 35% in government bonds, 40% in corporate bonds, and 25% in preferred stocks, as against an investment account two years ago of $1,209,000. Our income for the last two years from these investments has been $139,600.

Again we have realized $52,000 in rental income from those portions of our Home Office building unused by us at the moment, but available to us as we need the space to provide room for those people coming in to the Home Office with the expansion program that we are engaged in.

I mention also that we no longer have a mortgage payment to make. You will recall that we were obligated to pay $30,000 per year on the mortgage. With a favorable cash position prevailing for the last three years, we have been able to take advantage of a clause in our mortgage contract which allowed us to make an annual additional payment on the mortgage of $30,000 per year. With the building now completely paid for, our annual outflow of money has decreased in the amount of $60,000.

Plans are also afoot for the development and enlargement of our regional offices with the Los Angeles-West Coast Area to be the first to benefit from these plans.

Responsibility

These are some of the accomplishments which this Association has to its credit. Our books will reflect these items. There is one accomplishment which I would like to tell you about and which is not reflected directly in our books. The thing that I refer to, has been a direct effort on my part to bring into the office of Treasurer of this Association a feeling of responsibility to the needs of the individual member of this Association, as well as responsibility for the group as a whole. The door to my office has been completely opened, and human interest has been taken in the problems presented to us by or for the individual member. All of this has been done to help reduce

that temperature that I have been telling you about.

Getting on now with our books, the financial statements and associated papers which have been furnished you for this Convention—these financial reports tell two stories or show two pictures. In one instance, they report or show what has happened in the last few years. And from this, conclusions can be drawn as to what will happen in the next year or years.

As you can see, the cost of doing business since the last Convention has gone up. It will continue to rise. More demands will be made on our treasury. We are not necessarily getting richer by the minute, and that statement brings up a point which I would like to discuss with you. I refer to our dues dividend, so called, and the pros and cons as to the philosophy behind it. There is that school of thought that says: "Keep it—why give it back?" And another school of thought that says: "Cut the dues." I tell you now that I am for the dues dividend so called. I am not necessarily in agreement with its size. Its size, however, is something that is controlled by our Conventions, and I will explain this to you in a moment.

The Dues Dividend

The basic philosophy behind our dues dividend, as I see it, is that with a business such as ours, unpredictable to the extreme, you cannot forecast to any great extent, or with any reasonable degree of accuracy, just what our expenses will be. Remember, we are not a business that goes out and buys so much raw material, uses so much labor and manufactures so much in products. We're a labor organization. We are liable tomorrow to start out representing an individual member right down to the last brick in the building. So, with a dues rate of 1½% of pilot income, we have a rate that has so far produced more money than we have needed. Therefore, that money has gone back where it came from. In other words, we have a cushion.

On the other hand, and with our present dues structure, if you lower the dues to say 1% of pilot income in order to eliminate the dividend, then if your expenses were high, you might conceivably operate at a deficit, and eventually, to avoid going out of business, you would have to come back and raise the dues rate or make a special assessment. Raising dues is quite a process, I can assure you. With our present dues structure our dues rates adjust automatically. As expenses rise, the dividend falls; as the cost of doing business goes down, the dividend goes up. Now, one of the worst things that can be done in this Association is to go about jacking up, or down, our dues. The members never know where they stand. Delinquency goes up—confusion reigns. You will never know whether you can meet next year's expenses or not.

To that school of thought that says: "Keep the extra money—why give it back?", I say this in reply: "Why should I, as a member, work to build a solid Association and pass on to the new man who takes my place in the cockpit, not only a good organization, but my money as well? Let him supply his own money. I have already supplied him with a good Association on which to build." There are unions today not subscribing to this theory, yet well heeled to the tune of millions of dollars in their treasuries, who are raising their dues rates; and in these undemocratic organizations the individual member has nothing to say about it.

I mentioned that the Conventions controlled the size of the dividend. They do—why or how? Because it is through Convention action that most of our expenses develop. If you think big, you necessarily spend money. If you come out of Convention with little or no action, you don't spend. Right now in you own super markets you pay 59c a pound for hamburger or $1.19 a pound for steak. I am hopeful that this Convention likes steak. I am tired of hamburger.

All this has taken you a little way into my department in this Association. I would like to take you a little farther.

Reimbursement Problems

The last Convention stated in no uncertain terms—fix the flight pay loss reimbursement problem. I think you will agree that we have done that. You are now getting reimbursed promptly as you directed. We have gone even further than this. We are now actively engaged in the promotion of the idea whereby the air line companies themselves will maintain a member doing Association work on the company payroll, with reimbursement to them from ALPA coming once a month. This simplifies pay day for the member and guarantees to him his fair share of the fringe benefits in his working agreement. Hopefully we will have this arrangement on the majority of the air lines within the next two years.

Early this year, I became aware of the fact that the administration of our insurance program needed attention. This matter was taken up with Mr. Sayen, our President, and as a result my department took over the management of our Group Life and Loss of License insurance programs on March 1, 1956. A tremendous amount of effort has been expended in this direction. We have developed sharper, tighter, more positive methods of handling the administrative work involved in the two programs. We have reached a point now where we are absolutely up to date on every phase of this work. This phase of our work, although touched upon only lightly here, has been an accomplishment of which I am very proud.

We are also handling the billing and collection of advertising for THE AIR LINE PILOT magazine with some $500 to $600 per month being involved.

We have actively engaged in the adjustment of salaries for staff and clerical employees and, again with Mr. Sayen, worked out the increase, which you are aware of, in daily expense allowance amounts.

All this tells a story but still leaves untold the real story of the day to day hard, tedious work-a-day grind of the people on my staff and in this Home Office of ours and its regional offices, from the bottom man to the President, who, by their devotion, determination and perhaps basic love of the pilots and the flying profession, take your schemes, your thoughts and your demands and breathe life into them. We should be thankful that these kinds of people exist! Without them we would be lost.

Speaking As 'A Pilot'

This brings me to the end of my report to you as Treasurer of this Association, and I would like to talk to you now as a fellow pilot, who has had the privilege of serving you and this Association for some time. In doing my job at the Home Office and at the same time doing the job of line flying as a pilot, I have had a unique experience. I have been able to look at both sides of the coin at the same time. I have had perhaps a little closer look, a little closer insight into our problems and am, I think, qualified by virtue of this experience to pass on to you some things to think about, or rather to state it more forcibly, some things to take action on now before it is too late.

I would like to talk to you then about a weakness which is developing within our organization—and which, if allowed to grow, will bring us to our knees and destroy us. That weakness is the lack of attention; the desire to have without the willingness to work; and to lay it right on the line, the apathy and complacency among the general membership towards our Association. In saying this, I realize that we will never have that ideal Association, where every member will be completely informed on every issue and a paragon

of unionism. I also realize that we will always have our minority groups, the rightists, the leftists, the weak, the lame and the halt. We also will always have the free riders.

But I say this—and I say it as forcibly as I can—that we must find a means of reversing the trend which we have within this Association which thinks and acts as if ALPA were one large insurance company to which a member will pay dues, and for such payment receives the ultimate in job protection and rewards. Too many of us fail to realize that an individual membership is worth only what that membership contributes to the whole, and I am not speaking here of money contribution. Too many of us are content to elect Joe to do the job—and then after having done this magnaminous thing, we go away and leave Joe holding the bag on a job which he has little chance of succeeding at, because the rest of the tribe have folded their tents and softly stolen away, back to the golf course, the race track, the business venture—back to working out a good little deal for old age. So Joe fails. His wife beats on him. His company beats on him, and so do his fellow pilots; and when his term of office is up, you couldn't get Joe to take the job again, so help me Hannah! But you've lost a valuable man. You can extend that little statement right up to the top of this organization. Who loses on a deal like this? Every last man Jack of us. Not only collectively, but individually. Take a look at the last Council Meeting you attended. Were the old timers there—the new men—were all the available members there? If not, where were they?

'Hard Work'

Too many of us think that the Association is something that remains ready here in the Home Office, like a fire company; that all we have to do when we get in trouble is to say the magic word, and the answer to our problem will be immediately forthcoming. We fail to realize that each of us, singly and individually, is the Association, that there is no magic word other than the words "hard work." Nothing comes for free in this world.

Too many of us are prone to live in the reflected glory of just being an air line pilot. It's nice to be looked up to by our friends and neighbors, but I wonder sometimes how in the dark of the night we can live with ourselves. We all have feet of clay, but with some of our members that clay is getting pretty high on the hock. When are we going to stop hanging around the gates of the rumor factories, snatching up the last shred of misinformation on which to hang our hats? When are we going to stop criticizing the man in office and start doing a little work to help the job along, and when are we going to start accepting responsibility for our failures instead of hanging them on dear old Joe like a millstone?

There is a solution to all of this, and I think it can be summed up in one word—education. Education of our present membership, who in turn will educate the new member yet to come into the Association. Education of the membership as to their responsibilities to themselves and to the Association and along the lines of what can be gained on top of what we already have, if we only work together.

I hear a lot of talk about big pay increases in the forthcoming negotiations, and I am all for that. But I am not so much of a dreamer as to think that someone is going to step up and hand it to me. I think I am going to have to work a little for it. As a matter of fact, I might even have to give up a golf game maybe even once a week.

Calls For Action

I think it is time that every member dropped the broad brush attitude of saying: "The Association ought to do this," or "The Association ought to do that," and get into the fine brush attitude of saying: "What can I do to help this Association along the way to more of everything for each of us?" So, how do we reserve this trend? How do we change our thinking? How do we educate the people like the boy who wrote me the other day in answer to an expulsion letter of mine which had gone to him after a nine month's lapse in his dues payments? He said: "I am sorry but I can't pay any dues right now. I am getting married. I will try to take care of my dues right after the first of the year. Sincerely yours. . . " There's a boy who is building his house upon the sands. We have many like him. I am not quite sure how we should go about doing this. Perhaps the answer should come from our concerted thinking. I believe that we perhaps could do it by action on the part of the hard core membership of ALPA. If everyone of that hard core membership would take it upon themselves to spread the word, to bring into the fold just one more solid member of ALPA, we would lick the problem. I advocate immediate and positive action in this respect. I advocate an enlargement of the grass-roots core of this Association. I advocate that we occupy our position as the leaders in the labor movement in the air industry before some other group moves in on us. I advocate that we wake up that sleeping giant called ALPA.

A Pilot's Discretion

From THE TULSA TRIBUNE, *April 1, 1957*

Last year two Tulsa pilots, flying an oil company plane, were bucking heavy weather over Ohio when they noticed glare ice accumulating on the wings. They radioed Air Traffic Control in Pittsburgh for permission to change their assigned altitude so that they might go above or below the freezing level. ATC refused because other traffic had been assigned the other altitudes. The plane crashed and both pilots were killed.

Last week-end in Kansas City a TWA pilot was defending himself against charges of violating ATC orders and climbing 2,000 feet above his assigned altitude to one already assigned to a Capital Airlines plane. The TWA co-pilot, in support of his superior officer, testified that the plane was icing and beginning to lose flying speed, and that the pilot took the emergency action on his own initiative in the face of a lively possibility that he might crash with his 35 passengers.

Air Traffic Control is fine, but the man giving orders in a cozy office on the ground is hardly in a position to appreciate a real emergency in the air. The chance of the TWA plane running into the Capital plane was infinitesimal compared to the peril faced by the TWA plane.

One of the problems of bureaucracy is that, however well intentioned, it eventually gets around to considering rules more holy than common sense. The pilot is the best judge of an emergency, and if subsequent examination reveals that his plane really was in a jam he should certainly not be punished for making every effort to get out of it.

What ATC may forget is that if a plane starts to fall it is going to cut through the assigned altitudes of every plane below it while it goes on to disaster for itself.

Harness Design For Pilot Survival

There Is General Agreement That Harnesses Are Vital Survival Aids. On What Type, There Is Less Agreement. Here Is Another Discussion Of That Question

By Dr. Horace E. Campbell

Chairman, Automotive Safety Committee, Colorado State Medical Society

Studies in deceleration as related to the automobile have led the writer to an increasing familiarity with the literature of deceleration as related to the airplane. The harness configuration suggested by A. Howard Hasbrook *(Designing For Accident Survival,* THE AIR LINE PILOT, *September, 1955)* seems to this writer so patently dangerous that a word of caution is deemed appropriate.

This harness has one great advantage in that it removes, at long last, the shoulder straps from their attachment to the lap belt. That shoulder straps so attached do actually protect the head from injury (their primary purpose) is beyond doubt. Yet, shoulder straps attached to the belt also have the effect of raising the belt from its optimum position across the groins. At the groin, the impact of the belt is delivered almost directly to the skeleton at its most rugged portion, at the exact site of the hip joints, the strongest joints in the body. If any angulation of the body across the belt is to be done, it is far better that this occur at the hip joint than at any other site. In fact, the great efficacy of the lap belt in controlling rapid deceleration has been because it naturally falls into this groove *between* the abdomen and the thighs. Any modification which disturbs this relationship, is to be deprecated. The suggestion of Aviation Crash Injury Research releases the lap belt from this encroachment upon its excellent natural qualities and is therefore to be recommended.

Quotes Dr. Stapp

It is a matter of record that the current harness used in military aviation, pulls the belt up high enough to break the lower ribs. It leads to other injuries as well. J. P. Stapp records: "While this suspension solves some problems, it creates others. The forward motion of the shoulders during impact applies traction to the shoulder straps, raising the lap belt, permitting the lower half of the body to begin bending around it. The upper edge of the belt lodges against the lower margins of the ribs and against the upper abdomen . . . One subject sustained a broken rib cartilage at about 12 g . . . Finally, the unrestrained pelvis always moves forward in this harness, flexing the lumbar curve to the limit, so that it is in the most unfavorable position for receiving an upward force, such as might be encountered by a fighter plane making a belly landing on rough ground. A personal communication from the Directorate of Flying Safety indicates that lumbar and thoracic vertebral body compression fractures occur in sixty per cent of all fighter pancake landings, and eighty-three per cent of jet aircraft wheels up landings." *(Human Exposures To Linear Deceleration,* USAF Technical Report No. 9515, Part 2, December, 1951.)

To counteract the forces that were producing these injuries, Stapp devised a pair of leg straps, which had the double effect of holding the belt down and offering further surfaces for the absorption of energy during deceleration. A brief survey at two Air Force bases, revealed the non-presence of these leg-straps so far as anyone that I contacted knew about, and leads to further wonderment on the part of this writer as to the cause of the nearly five-year lag in the acceptance of this modification.

The H-V configuration as suggested by Aviation Crash Injury Research.

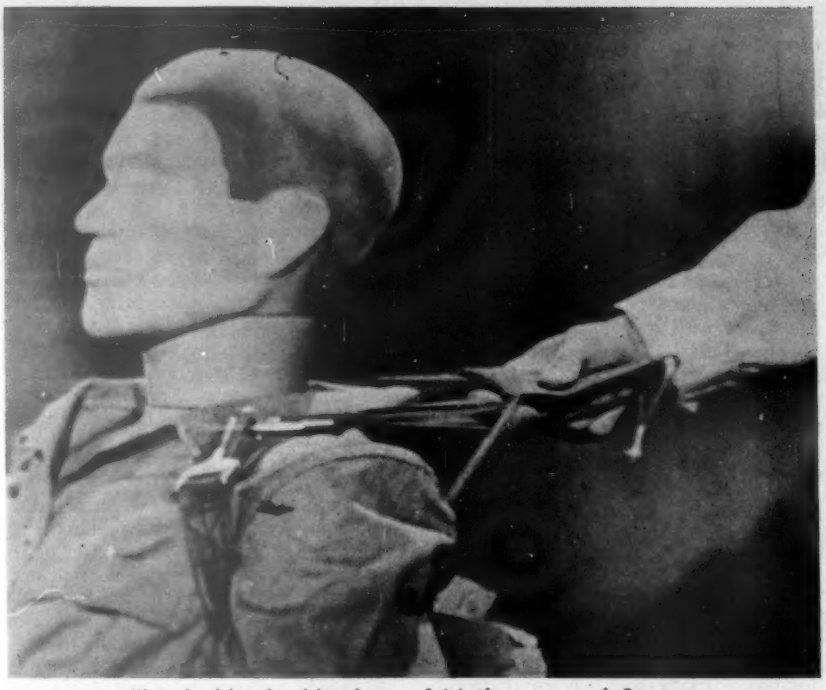
Lauds Av-CIR Proposal

Thus, again, this writer commends Av-CIR for introducing the idea that the shoulder straps logically should attach elsewhere than to the lap belt. The breaking out of this groove, into which the authorities have become fixed, marks a great advance.

Despite the advantages of the proposed Av-CIR arrangement, these seem to this writer to be overshadoved by a *greater* disadvantage. The attachment of the forward ends of the shoulder straps to a point both forward of and much below the shoulders, causes the resultant of the forces imposed by the shoulder straps to be largely *downward,* in a direction almost parallel to the subject's spine. The motion, which the device is to counteract, is a motion *forward,* at a right angle to the line of the subject's spine. Thus, these shoulder straps would actually cause an enforced flexion of the spine, at the lower thoracic level, placing the spine in a position vulnerable to the upward forces which are always present in aircraft crashes, and ensuring the continuation of the spinal injuries which Stapp hopes to prevent by the use of legstraps. Furthermore, this arrangement of the shoulder straps would actually augment these spinal injuries by adding their "down" forces to the "up" forces through the seat. If there is anything the crashing pilot does not need, it is additional "down" force.

The Chest Belt

The three-inch chest belt, which some of the air lines have furnished to their pilots, has seemed to this writer to be a logical and effective complement to the lap belt. This belt is almost never used, however, because it is too



The double shoulder loop of Mathewson and Severy.

restrictive and was therefore almost never in place when it was needed. Equipping it with a lightly loaded, impact-locking reel, mounted on the bulkhead behind the seat, would seem to this writer to transform it into a usable and thoroughly effective device which the pilot would be willing to wear at every take-off and every landing. This he must do, if it is to become the safety device that it is intended to be. Certainly, as thus modified, the chest belt directly counteracts forward forces, without any tendency to produce compression fractures of the spine. It leaves the lap belt unencumbered, and together with the real and quick-release buckle now used, is no more restrictive of operative movements than the Av-CIR configuration.

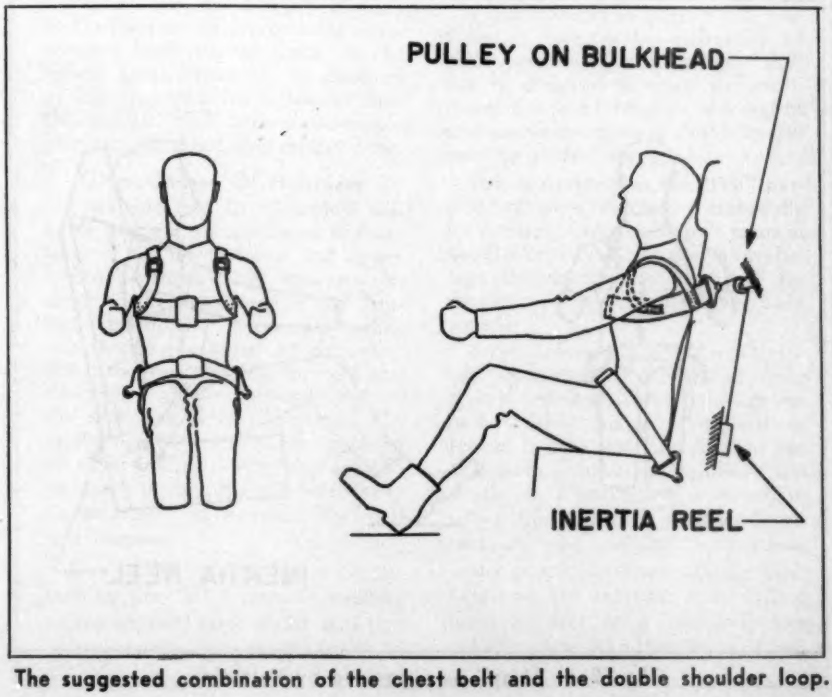
Double Shoulder Loop

Recently, a new strap configuration has been proposed which seems to this writer to have great potentialities, in both the aircraft and automobile fields. This is the "Double Shoulder Loop" of J. H. Mathewson and D. M. Severy. (*See* Automobile Impact Research, *Trans. National Safety Council 28, 1954*). It is attached at a point in the seat back at the level of about the fifth thoracic vertebra. Two loops of two-inch webbing, one over each shoulder and under the arm, pass back to the same attachment point. In their experimental work, this configuration seemed to be more effective than the chest level safety belt, but this would seem to be due merely to the fact that the three-inch chest-level belt stretched enough to allow the experimental dummy to strike his head on the steering wheel (this study was conducted in automobiles). Correction would seem to indicate wider nylon, or nylon with lessened stretch characteristics.

In any case, it is not the purpose of this writer to argue about the relative characteristics of the chest belt as opposed to the double shoulder loop. Rather, it is his purpose to combine them in what would seem at this point to be the best device thus far proposed.

Neither of these devices, nor the composite device, has the defects of the current shoulder straps or of the proposed Av-CIR shoulder straps.

The chest belt may be thought to impose too much force upon ribs and to result in rib fracture. The three-inch chest belt *is* too narrow; it cannot cover more than two ribs at the front of the chest. Thus, the minimum width for a chest belt would seem to be four inches. The double shoulder loop, on the other hand, applies force only to the shoulders and this is transmitted to the thorax through the muscles and the clavicles, a rather "stretchy" arrangement. It would seem entirely logical to combine these two devices and to distribute the forces both to chest and shoulders, with increased



The suggested combination of the chest belt and the double shoulder loop.

area distribution and better anatomical distribution.

Belt Arrangement

To reduce bulk, the two-inch shoulder straps should be stitched in their natural oblique direction to the four-inch chest belt, just below and a little behind the armpit and again at the point of termination. The four-inch webbing passes through a suitable metal fitting to which the cable from the impact locking reel is attached. Through a rectangular aperture in the seat back, measuring about six inches by six inches, the engagement is made to the reel. This is mounted upon the bulkhead behind the pilot or upon the floor, with a pulley on the bulkhead. When the pilot sits back against the seatback, all metal parts have passed through the aperture to ensure his comfort.

Further, on anatomical grounds, it is suggested that the straps be so adjusted by each wearer, that upon impact the first strain be placed upon the shoulder loops, and then (at an empirically determined point) the strain be assumed by the chest strap. Thus in ordinary wear, the chest strap is loose across the chest, but is held up by the shoulder straps, upon which is placed the constant load of the inertia reel. Thus is maximum comfort achieved with a minimum of restraint.

Concerning the shoulder loops, the difference in size of personnel will be compensated for by the distance behind the pilot's back at which the webbing engages the metallic fitting. This can be arranged to fit the largest pilot and will, by virtue of the loaded reel, fit all smaller individuals. The presence of a quick release, adjustable buckle at the front of the four-inch webbing is understood, of course.

The conventional shoulder strap arrangement, even with the addition of the leg straps suggested by Stapp, has the one advantage that all elements fall apart with the release of the one buckle. This is a real advantage, but of less importance than the principle that the shoulder straps must not add to the compression forces to the spine.

Pilot Reaction

In discussing my combined chest-and-shoulder-loop configuration with several air line pilots I have encountered an amusedly tolerant reaction combined with a patronizing pat on the shoulder. They say something like this, "Thanks for the interest, Doc, but up where we sit it does not make any difference whether we have shoulder straps or not."

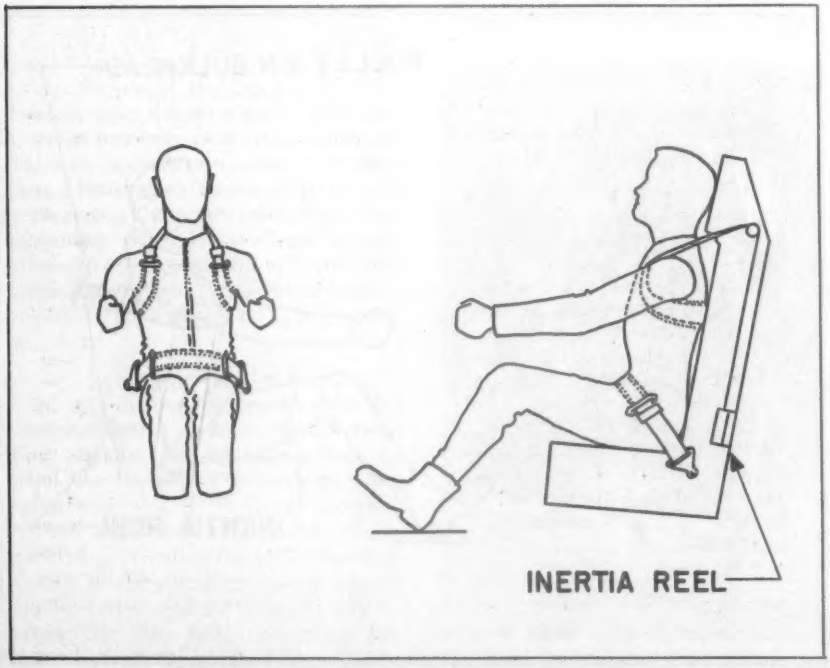
It certainly does not make any sense to provide 20 G belt protection in an airplane stressed to a forward loading of only 9 G. In this writer's opinion, the time is already here when the air line operators should agree upon an increased forward emergency load factor. It is somewhat unrealistic to employ 20 G belts for passengers in a 9 G airplane. The military experience with the 40 G fighter airplane and the remarkable saving of personnel achieved thereby points clearly to the need for stronger, as well as faster and larger, airplanes on our airlines.

Furthermore, the publicity attendant upon the Grand Canyon disaster brings out that visibility in the nose is "nothing to brag about." I suggest that this portion of the transport airplane be used for baggage and such expendables, and the control area be shifted to some less vulnerable area. I am told by some individuals in the industry that this is not as silly as it sounds.

Stanley Aviation Harness Design

My thinking concerning harness design for pilot survival had reached this point when a chance encounter with Stanley Aviation personnel revealed that they had strikingly similar ideas for pilot harness design. They make what seems to me the brilliant further suggestion that the pulley site be placed upward toward the top of the head, thus converting the resultant into a greatly needed "up" force. (*See* Preliminary Design Study Of Upward Ejection Seat For Short-Range Aircraft, *by G. Valentine, Stanley Aviation Corp. Document No. 355.*) Thus, they concur in the principle that the lap belt must not be encumbered and distorted by shoulder straps. Their suggestion that the shoulder strap inertia reel cable be carried *upward* to provide lift, rather than compression, for the spine marks a significant new advance.

The pressure applied by the strap across the back and in front of the shoulders counteracts all tendencies to flexion deformities of the spine. In strong *forward* deceleration it would seem to me that the straps would tend to spread apart and to apply excessive pressure to the nerves and great vessels of the arms. As designed by Stanley, this strap configuration is to be integrated with the flying suit and thus a tension member across the chest between the two straps is provided. In the use of this device by air line pilots, the addition of a four-inch strap across the chest with a quick release buckle is suggested. This, together with the high angle of attachment of the cable, seems to me to make this configuration a more effective device than the combination which I have proposed. The only objection might be that it is not quite as comfortable in use over an air line pilot's uniform as the device I have suggested, which allows the chest



The "Back Strap" as suggested by Valentine.

strap to remain loose during ordinary wear.

In any case, both the Stanley configuration and the proposed composite configuration avoid the spinal compression feature inherent in the Hasbrook proposal. The suggestion in the Stanley proposal, that actual "lift" be afforded to the crashing pilot, is augmented further by the addition of a descending seat pan, further to relieve the spine of compression forces.

The suggestion of Mr. Hasbrook that a light-weight crash helmet be worn in the cockpit of transport planes is too sensible really to heed further comment. It will meet with emotional opposition in several quarters, but just as construction and oil workers have been led to wear their tin hats as a badge of courage, so the air lines' pilots can be influenced. Certainly, little or no opposition can be expected from the flying public whose lives are in the hands controlled by the heads so protected.

Pilot safety is something that we all desire; one big reason being that we are all in this ship together. Cooperative study by all concerned, can make this mode of transportation even better than the excellent service it already is.

Summary

▶ There are two main defects of shoulder straps attached to the lap belt: 1) the lap belt is raised from its ideal location at the groin to a much more dangerous and much less effective place across the abdomen, and 2) compression forces are applied to the spine which is already assailed by "up" forces through the seat pan.

▶ In those shoulder strap configurations which do not attach to the belt, the former defect is obviated, which is a move in the right direction. The attachment of these shoulder straps to a point *below* the seat belt makes undesired compression forces even more severe.

▶ A separate chest strap eliminates both of these defects and the addition of shoulder loops provides a greater area for body contact.

▶ The idea of attaching the shoulder strap to a point *above* the shoulders adds a significant new development to restraining devices. The "back strap" configuration applies forces directly counteracting the undesired spinal flexion forces. The provision for a shock absorbing seat support structure ameliorates those "up" forces which produce compression injuries of the spine, and increase the effectiveness of the upper torso restraint.

And In Rebuttal...

An Unused Harness Is Useless And Harness Design Must Also Incorporate Non-Restrictive Comfort

Safety harnesses as a principle have been thoroughly acknowledged, but design-wise have given rise to some controversy.

The September, 1955, issue of THE AIR LINE PILOT *carried an article entitled* Designing For Accident Survival, *by A. H. Hasbrook, Director, Aviation Crash Injury Research of Cornell University. This article recommended a type of harness with which the author of the accompanying article, Dr. Horace E. Campbell, took issue. In view of the fact that Dr. Campbell's article specifically mentioned Mr. Hasbrook's work and recommendations, it was submitted to him for his comments with the full concurrence and approval of Dr. Campbell.*

Following are Mr. Hasbrook's remarks:

Thank you very much for permitting me to review Dr. Horace Campbell's paper, entitled *Harness Design for Pilot Survival.*

Dr. Campbell's suggestions concerning the desirability of incorporating a "suspension type" of harness, which would decrease the compression loads on the spine, is obviously good. However, we disagree at this time with his statement that the Av-CIR "HV" harness drastically increases the down load on the spine.

Cites Causes Of Fractures

I am sure that Dr. Campbell will agree that the primary cause of fractures of the lower dorsal and upper lumbar vertebrae are due, not so much to the magnitude of the compressive load, but are caused by undue flexion—bending—of the spine when the buttocks slide forward and downward as the forward edge of the seat pan flexes downward. In addition, the compressive qualities of most seat cushions increase the tendency of the hips and buttocks to "submarine" underneath the belt and harness.

One of the prime reasons for attaching the "HV" harness webbing to the forward edge of the seat pan —between the legs—was to apply an "up load" to the seat pan, which in turn would resist the "down load" imposed by the buttocks; this "up load" would prevent the downward flexion of the seat pan and thus reduce the possibility of acute flexing of the lower spine.

We quite agree that the Av-CIR "HV" harness is not the ultimate, but we feel that it is an improvement which will aid in decreasing the serious and fatal injuries currently sustained in cockpits of transport aircraft — in survivable-type accidents. Furthermore, a test program has shown that the majority of pilots find the "HV" harness to be so comfortable and nonrestrictive, that they feel that they will wear the harness routinely on take-offs and landings.

Depends On Pilots' Acceptance

Undoubtedly, a more ideal harness such as the one proposed by Dr. Campbell would do a better job—protection-wise—but it would prove ineffective in accidents if pilots will not wear it due to discomfort and/or restrictiveness.

I would therefore suggest that new types of harness be evaluated by pilot personnel in order that they can be designed to reach the maximum acceptable degree of comfort and non-restrictiveness that is necessary for air line operations.

It is our hope that the "HV" harness will soon be tested dynamically by perhaps, Colonel Stapp's team at the Holloman AF base; certainly, before this harness is produced for routine air line use, it will have been tested.

I certainly agree with Dr. Campbell that shoulder harness of some type is a definite "must" for air line crews; what many pilots fail to realize is that they can lose an eye or sustain serious concussion—if not death—in a survivable accident, in which the cockpit is completely intact. As you probably well know, many people die from striking their heads on the sidewalk after falling only six feet at a relatively low velocity—less than 10 miles per hour.

The ALPA Camera

Retirement Problems

W. H. Proctor, former AA captain, first pilot member of ALPA mandatorily retired under company policy for having reached age 60, outlines his views on how the Association could provide services for retired members, in talk before ALPA Executive Committee during its last meeting at the Home Office, in late April.

WAL MEC

Represents ALPA

Barbara Galinski, Home Office Receptionist, represented ALPA in the Queen's Court of the Air Force Association Convention, held in Chicago, April 27.

UAL MEC

BNF MEC

EAL MEC

New MEC's

Familiarization with the Association's departments and a briefing on ALPA's policies and programs were part of the recent organizational meetings of new MEC's held at the Home Office.

NEA MEC

NOR MEC

TWA MEC

AA MEC

The Airway Squeeze-Play

Or, How To Get Your Backfield Shifted

By Capt. G. W. Henderson
UAL

At this writing, I am one of a number of fortunate souls who has never had to execute an "Emergency-Action" maneuver in order to avoid colliding with another airborne aircraft, because of the fact that the two close-calls I have experienced happened so fast that I found myself completely powerless to take any evasive action whatsoever. Frankly, I am quite concerned about the number of aircraft I have spotted coming towards me from either dead-ahead or off to *my* right while my own position is 2 or 3 miles to the right of the center line of a VOR airway.

There was a time when just about every aircraft you saw (or didn't see, for that matter) would be well off to your left, and pilots would instinctively give themselves that additional margin of safety by staying well to the right of the radio courses except for those times when it was necessary to pin them down for precise navigational purposes. It was almost an unwritten law that aircraft approaching a terminal under IFR conditions would have exclusive rights to the "on-course" signal, particularly if an instrument approach was called for at that terminal, and by the same token, would give wide berth to the range legs on departure. Under VFR conditions, by day and particularly at night, it was general policy to stay well to the right of the course, entering or leaving a controlled area.

Spotting An Aircraft

We all know that an aircraft can best be spotted if it is *at least* 10 to 15 degrees to the side of dead-ahead. During daylight hours an aircraft's motion can best be detected against relatively stationary backgrounds such as clouds, irregular horizons or ground patterns, but the *degree* of motion is still dictated by the *angle* of observation. At night, an aircraft that is near dead-ahead and back-dropped by a star-filled sky, the confused lighting in our big cities or the scattered lights of a countryside, will be almost unrecognizable until a slight up or down motion (by virtue of its relative altitude) can be detected.

It is not to say that aircraft flying well to the right of a radio course are without hazard, but there would be some consolation in the thought that the aircraft you may have picked up dead-ahead would, generally speaking, be going in the same direction as you. That is, up until the CAA indicated its conception of VOR range flying, as set down in CAR 60.45, which I quote:

"Aircraft operating along Civil Airways shall be flown as follows unless otherwise authorized by ATC:

"(a) Along a low/medium frequency airway, aircraft shall be flown to the *right* of the center line of such airway.

"(b) Along a VOR airway, aircraft shall be flown on a radial designated as forming the *center* line of such airway."

Parenthetically, it would be much like the National Safety Council printing a government sponsored bulletin to the effect that:

"(b) Now that white dividing lines have been painted down the centers of our Nation's Highways, vehicular traffic will straddle the *center* line until such time as a head-on collision becomes imminent; then both vehicles should institute movements to their right, which we feel, should take them both out of harm's way."

It would be comparable, in example, if our nation's roadbuilders were ordered to narrow down the width of future highways, even when they knew that there would be approximately 100,000 cars, over and above the normal traffic expenctancy, passing over that route during the following year.

If you have a one-track railroad, you must necessarily have sidings where trains can be shunted out of the way of trains running in the opposite direction, and you must have unerring dispatchers who can always put square pegs into square holes. And further, you must have highly alert engineers who must be capable of handling the potential of such a hazardous operation in case someone gets their signals crossed. In other words, over and above the natural hazards of the job and the many unforeseen "quick decisions" that inevitably occur, there is the human being to consider.

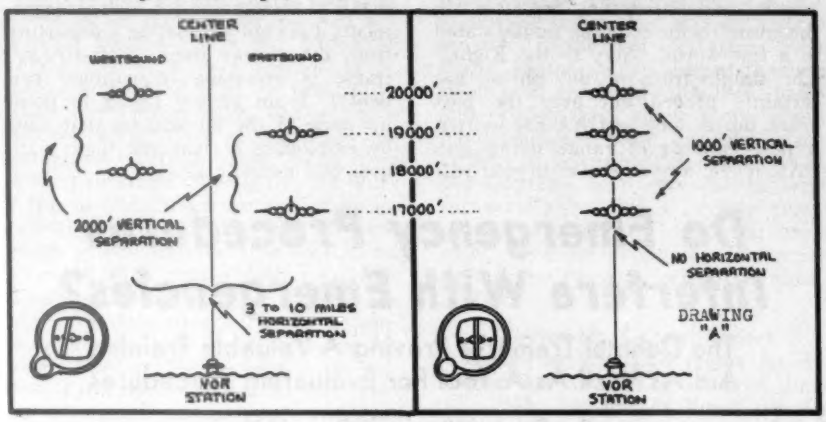
As long as man runs railroads and flies planes there will be built-in moments of danger, and it would certainly indicate progressive thinking if all of us took advantage of every element of safety, however small. It would be very shortsighted, and certainly over-optimistic, to think that one new radio-navigational device, precision-like though it may be, could revolutionize a high-speed transportation medium. Basically, the VOR has engendered another long stride in the direction of more accurate navigation with its static-free reception quality, its easily interpreted vertical needle presentment and a proportionately high degree of accuracy, but, like most electronic devices, its use must be tempered with an understanding that it is merely a means toward an end, not the ultimate instrument. As Queeg would say, "Mistake me not!" I have no quarrel with the basic principle from which VOR was born! My primary concern is *how it has influenced the manner in which an airway is navigated, and the gradual loss of a standard rule of flight safety!*

Flying The Airway

With reference to drawing "A," let us assume the following flight conditions: If, for example, four aircraft, two eastbounds and two westbounds, flying at 17,000 and 19,000, 18,000 and 20,000 feet respectively, are navigating down the center line of a VOR airway, they will have only 1000 feet of vertical separation from each other, and *no* horizontal separation. If any one of these four aircraft was subjected to weather turbulences, a flight irregularity or an Emergency Descent, it could conceivably give any one, or all, of the other planes some anxious moments.

If the above situation seems too hypothetical or remote, let us consider the hazard potential if we had projected these same four aircraft into an active weather front over the Great Plains.

Without applying *any* other unusual flight occurrence, the possibility of an in-flight collision is evident. As long as ATC considers all aircraft on the airways to be flying the center line, they will be unable to grant changes of altitude until a necessarily huge gap exists between traffic going in *either* direction. It used to be that your



Drawing "A"

pertinent traffic was someone going in the same direction as you, but nowadays, *every* aircraft on a VOR airway within 100 miles of you is *vital* traffic when considering modern-day interception speeds. As the result of this additional traffic (not necessarily new equipment, not added schedules; just the same traffic you always have around you on that same flight, but now placed *closer* to you by the wording in CAR 60.45, paragraph "b"), ATC, upon receiving your request for a better flight level, offers you the only alternative they feel able to give, and that, the now famous (or infamous?), "You are cleared to maintain 1000 feet on top of all clouds—make changes of altitude in VFR conditions." And so, suddenly, you find that in your efforts to give your passengers a well-ordered flight or by-pass an area of possible congestion or turbulence, you have, upon acceptance of that type of clearance, taken over the entire responsibility of traffic separation, *both* vertically and horizontally. *You have asked for a serving of lamb, and they handed you goat!*

Navigation

I am aware that the electronic experts have finally conceived a circuit in the VOR indication system that will allow only one full swing of the needle instead of the wild oscillations we are used to when passing over the general position of the VOR range station. Even after this circuit is added, it will still remain true that a 90 degree position, off to the side of the range, will give the most accurate indication of the passing, and will satisfy the perfectionist who deals in seconds because of present day and future ground speeds.

The drift imparted to an aircraft will be as evident when the needle lies *adjacent* to the center indice as when perfectly lined up. It wouldn't be as precisely exact as center-needle presentment, but I am inclined to defy an argument that would say that the few degrees involved could materially affect the safety or conduct of a flight.

Experimentation will show that it is far easier to fly along the side of the center line of the VOR airway, with the needle about 2 to 4 widths from the center indice, rather than keeping the needle centered at all times. If drift towards the airway center line becomes evident, you might like to think that, at least, you aren't crossing over into the face of on-coming traffic. There is absolutely nothing radical nor irregular about this method of flying the ranges—you would continue to use the designated heading of the leg, and then keep the needle off to the left of the center indice.

Radar

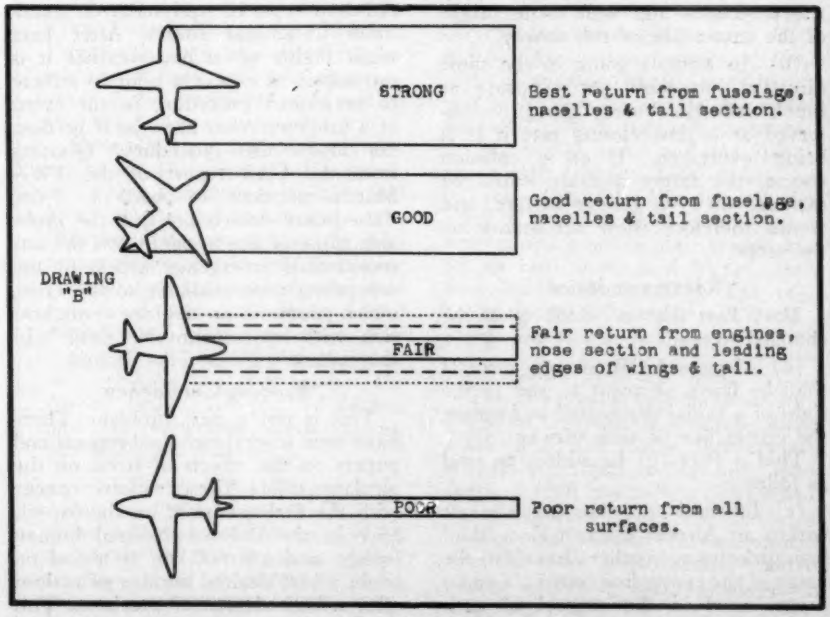
The return signal presentation on the radar scope is directly proportional to the amount of reflectible surface exposed by the target. An aircraft 45 degrees off to the side will show on the scope minutes before one dead-ahead at the same distance.

True, an aircraft coming towards you will be a better target than one going away (because of the relatively flat areas at engine nacelles, the leading edges of airfoils and the nose section, as compared with the knife-like trailing edges of airfoils, nacelles and tail section) but considering the rate of closure involved with high-speed aircraft, it would be considerably advantageous to have aircraft targets at an *angle* to the lubber-line of your radar scope. Refer to Drawing "B" which shows, in a general way, the reflectibility of aircraft targets in certain positions.

Advantages Of Flying To The Right Of Any Radio Range Course

1. Inbound aircraft could use the center line for checking the changing drift, the crossing of important intersections and offer a more positive identification echo to ground radar.

2. The Control Center could offer a safer and speedier climb-out vectoring service to outbound traffic.


STRONG
Best return from fuselage, nacelles & tail section.
GOOD
Good return from fuselage, nacelles & tail section.
DRAWING "B"
FAIR
Fair return from engines, nose section and leading edges of wings & tail.
POOR
Poor return from all surfaces.

Drawing "B"

3. (a) In cruise, on IFR clearance, there would be a *2000 foot* vertical separation between you and *any* other controlled aircraft going in your direction, and a horizontal separation of between 3 and 10 miles from other aircraft going in the opposite direction.

(b) In cruise, on VFR flights, DAY: You would have a better chance of spotting traffic coming towards you if an angle had been established by both aircraft being to their right of the airway. By virtue of the *angle,* the motion of objects become more evident inasmuch as they would be set against relatively stationary backgrounds such as clouds, irregular horizons, ground patterns, etc. NIGHT: The motion of another aircraft can best be seen when viewed at an *angle* against stars, or city and country ground lights.

4. Passing to the right of a range station and at an angle of 90 degrees will give an accurate ground speed check.

5. If it becomes necessary to execute an "Emergency Depressurization and Descent," it could be begun with some confidence in the knowledge that at least the next 2000 feet below you should be traffic-free. If the nature of the emergency demanded your descent through a *number* of traffic levels, you might like to feel that the center-line of the airway is available for the orientation and conclusion of your emergency.

6. (a) The probability that another aircraft will appear on the radar scope will be enhanced by the angle constructed by two aircraft flying in opposite directions and well to the right of the center line of the airway.

(b) An aircraft going in the same direction, although not exposing as much reflectible area, could be observed at a slow closing rate if it is being overtaken. If on a collision course, the target aircraft would be exposing an even greater surface, and would therefore show up sooner on the scope.

Recommendation

That Part (b) of CAR 60.45 be changed to read:

(b) Along a VOR airway, aircraft shall be flown adjacent to and to the right of a radial designated as forming the center line of such airway.

That a Part (c) be added, to read as follows:

(c) Inbound and landing aircraft within an Airport Control Zone shall have priority over other aircraft in the usage of the center line courses of radio ranges used in the control of such aircraft.

Perhaps these conclusions may seem lengthy and overdrawn, for after all, the entire theme could be simply stated in a few words, "Stay to the Right." The simple truth of this phrase has certainly proved out over the past years, but as long as CAA has written a new concept of range flying into CAR 60.45, any objection to that ruling must necessarily be explained in detail to show cause for such disagreement. I am not advocating a departure from the airway itself, ("off-airway" traffic is becoming increasingly evident!) I am merely trying to point up some of the advantages that exist by employing a right-side flight path over our nation's airways.

Do Emergency Procedures Interfere With Emergencies?

The Dehmel Trainer Is Proving A Valuable Training Aid As Well As A Tool For Evaluating Procedures

By Capt. Warren LeRoy, UAL

Chairman, UAL Dehmel Coordinating Committee

Ever since the Link Trainer, pilots have been irritated by the thought of flying ground-bound machines that supposedly simulate flying characteristics. In the two years that United has been using the new "idiot box," the pilots are learning to respect it more. It has reduced the collision and training accident problem, increased our proficiency level, and pointed up glaring defects in equipment and procedure. It is becoming apparent that the Emergency Procedures are too long and complicated for the average pilot to perform with any degree of consistency.

Before I offend any pilot's professional integrity, let me mention that many pilots are required to fly several different types of equipment on sometimes unfamiliar routes. After long night flights or in bad weather it is unrealistic to expect a pilot to adhere to prescribed procedure in the event of a fire, etc. What happens if he does not follow this procedure? Quoting from the CAB report of the TWA Martin accident of April 1, 1956, "The board determines that the probable cause of this accident was the uncoordinated emergency action in the very short time available to the crew, which produced an airplane configuration with unsurmountable drag." In the layman's terms, Pilot Error!

Building Confidence

This is not a new problem. There have been several technical reports and papers on the effects of stress on the airplane pilot. These reports concur with the findings based on the experience in the Dehmel. Normal human beings, under stress, can be relied on to do a very limited number of actions with a high degree of precision. This refers to the number of items to be accomplished from memory while performing the normal duties of flying. It is also evident that this stress seems to be reduced as soon as the important step of discharging CO_2 has been accomplished. As soon as stress is reduced the proficiency level increases with very few or no mistakes occurring after this. CO_2 discharge should then be earlier in the procedure. It appears to be a confidence building step that symbolizes success. This confidence is all important in handling emergencies.

Along with the confusion due to the over-all length of the procedures, we have improper presentation on the check lists and improper allocation of duties. We can all memorize the 12 immediate action steps for the DC-6 cabin heater fire and may well be proud of our ability to recite them while doing many other unrelated things. But when the bells and lights are on and you see one crew member doing step No. 5, another doing step No. 3, or No. 7, or perhaps a wrong step, it is very difficult to correlate what is being done and what is being omitted. Quoting again from the above report, "The Board must conclude that each pilot reacted to the emergency as he understood the emergency but, as the two pilots had not full common knowledge of what was happening nor precisely what the other was doing, the resulting joint and uncoordinated actions resulted in a windmilling propeller making the aircraft unflyable under the circumstances." Even the Dehmel instructors who do this all the time find it quite difficult to follow what each man is doing.

Common Problems

There has been a lot of ALPA activity and resentment about the accident

report mentioned above. Was this pilot error or an error in the over-all approach to the emergency problem? These men were in a position to be better acquainted with the procedures than the average pilot, one a check pilot and the other getting ready for promotion. Certainly they must have known the steps thoroughly; but what happens when these are applied to an actual emergency? The TWA procedures may be different, but the United ones are such, that a similar incident could easily happen to us. We have three separate procedures for a common ailment, one for a fire, one for engine failure, and a third to be followed if it occurs during take-off. Two of them say that the throttle and mixture must be operated first and the other one contradicts this because it would de-activate the Auto-Feather and there is the possibility of getting the wrong mixture at a critical time. It is not difficult to visualize a pilot in a CV 340, in attempting to evaluate which procedure to use, closing the throttle for an engine failure on take-off. In the ensuing confusion, the results might not be too different from the TWA accident. Is the pilot at fault for responding to normal human behavior? The ironic part is that it would most likely happen to the pilot who conscientiously memorizes all three procedures.

Did I say three procedures? There are thirty pages of Emergency Procedures in the DC-6 Manual alone. There are 425 words for the Cabin Heater fire. I mentioned that it seems impractical to memorize the 12 immediate action steps for this procedure if you cannot follow the successful completion of it. To think in terms of the 21 steps for the complete procedure is negative training. Yet some check pilots tend to give a better grade to the pilot who can recite every word on every page. I think we need a more objective system to evaluate a pilot's performance. Encouraging this detailed memorization may be detrimental to the actual objective.

Procedures Vs. Emergencies

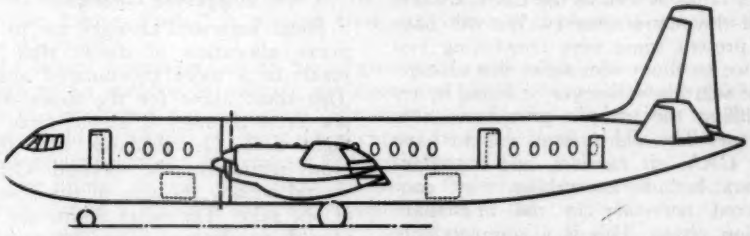
It is true, the manual states that it is a guide and that we shall exercise judgment to deal with these things as they come up. Does this mean that we can ignore the lengthy procedures and devise some of our own? Many pilots have indicated that they would do only the important steps to be sure of handling the emergency. Is each pilot to have his own set with no regard to what the rest of the crew may be thinking or doing? Sadly enough we have reached a point where too many people are dictating what we shall do. Unless we do as they say, we subject ourselves to the ever increasing "Pilot Error" stigma. May I suggest that the pilots who are faced with these problems daily may know more about handling them than they are given credit. In discussing this with one of our Captains, who very capably and successfully handled a serious emergency, he made the following comment, "We are letting the emergency procedures interfere with the emergencies."

Quotes Mt. Carmel Report

Reviewing the CAB report on the United Mt. Carmel accident of June 17, 1948: "A fire in flight permits little opportunity for the exercise of detached and thoughtful consideration of emergency procedure. Immediate action is required if a fire is to be controlled. Too little consideration has been given to the psychological and physical limitations of crew members in time of stress and danger as related to the complexity of emergency fire procedure. It is not safe to assume that the pilot and copilot, under emergency pressure, will always adhere rigidly to the sequence of steps outlined in the CAA Approved Airplane Operating Manual.

"The possibility of human error under great mental stress is well documented in air transport experience and the design of aircraft controls, especially those of an emergency character, should take into consideration the natural limitations of human nature. These limitations argue against involved procedures applicable in emergencies. In harmony with this objective, the Douglas Aircraft Company has designed and is testing a modified fire extinguishing system which will

On The Cover



Side view of "Vanguard", showing "double bubble" design.

The recently-announced order by Trans-Canada Airlines for 20 Vickers Vanguards, with an option for an additional four, will introduce another British turbo-prop aircraft to the North American market.

Generally regarded as the successor to the Viscount, the Vanguard, a Vickers-Armstrongs product, will be of "double bubble" fuselage construction; the top portion for passenger accomodation and the lower part for freight, which divided into two cargo holds, will have a total capacity of 1,410 cubic feet. The wing span will be 118 feet, the overall length: 122 feet 4 inches, the overall height: 34 feet 11 inches, and the maximum cabin interior width: 10 feet 9 inches.

Performance Data

In the TCA version, the Vanguard will have a maximum take-off weight of 141,000 lb., a maximum landing weight of 114,000 lb. and a payload of 24,000 lb. With Rolls-Royce Tyne engines of 5,315 t.e.h.p. the cruising speed will be over 420 m.p.h. Effective stage range in the worst Canadian winter conditions will be 1,750 miles, and, with a payload of 21,500 lb., the still air range will be 3,000 miles and the stage range with reserves, 2,600 miles.

Trans-Canada's Vanguards will carry 82 first-class or 102 tourist passengers and a mixed class version of 60 per cent tourist and 40 per cent first-class is also possible. The interior layout will include four washrooms and two galleys.

1960 Delivery Date

The Vanguard will be used by TCA on high-density domestic and southern service routes. Delivery is scheduled to start in the early autumn of 1960 and will be completed by mid-1961.

The total number of Vanguards now on order is 40, with 20 purchased earlier by British European Airways.

permit all necessary steps to be executed by the movement of one control. An additional vent is also being designed to reduce CO_2 concentration in the cockpit. etc."

Increased Complexity

More than five years elapsed from the date of the above report to the advent of the DC-7. What happened to the one-control movement procedure? The present emergency procedures are now more complicated and involved than those in use at the time of the report. Our Central Air Safety Chairman has recently studied the DC-6 Electrical Fire procedure with some of the Company engineers. They estimated that the entire procedure including actuating all the circuit breakers, waiting the necessary time to check each circuit for fire, etc., would require three hours or more to complete! This is not in harmony with the objective as referred to above and is indicative of the changes that are necessary.

There are always those who oppose any change. These men are in our own ranks as well as the CAA, United, and the manufacturers. We will have to present some very convincing evidence to those who resist this change. The solution will never be found by reshuffling the archaic procedures now in use. The old system was to have the CAA, air carriers, and manufacturers include everything they considered necessary in the immediate action phase. This is a commendable approach, but by the time all suggested items are added up, the procedure is too long to allow for pilot capabilities. We are now learning that it is not practical to expect a pilot to do more than three or four immediate action items. When more are included the efficiency level drops to the point that only a portion of the steps are performed and quite often one or more of the wrong engines are shut off. This is true even though we know more or less what to expect before the beginning of the training flight. Is it better to try to do the lengthy procedure with little concentration on flying or successfully execute a shorter procedure and keep the airplane in the air? The procedure should be no longer than a pilot can normally be expected to do. This may require combining two or more items in one operation and placing the less essential items later in the procedure after reference to the check list. It is a bold new approach but we must meet the challenge.

Psychological Effects

Before getting on with some proposals, let us touch on the psychological effect of this. I mentioned that confidence is an important factor in determining the success or failure of an emergency problem. You may well be able to handle it, but if you do not *know* that you can, the chances are you may not carry it to a successful conclusion. We then must develop something that we all have confidence in. This confidence will go a long way toward reducing the over-all mental stress imposed on the pilots of modern aircraft. The rate at which pilots are failing to pass the physical examinations, because of mental reasons, is ever increasing. Remember how much your loss of license insurance premiums have gone up? If the simplification of the emergency procedures gives us a safer operation as well as reduces the stress, it then becomes imperative that we do so. How much less anxiety about the hoodchecks would exist if this phase were improved to within practical limits. We could begin to think in terms of "inconveniences" instead of "emergencies."

Suggested Changes

Some suggested changes are to improve allocation of duties that will result in a more coordinated action. This must allow for the times when one crew member is absent from the flight deck. On airplanes with three crew members, the Second Officer should occupy the seat in the absence of one pilot. The other flights are not of such duration as to require or justify either pilot to be out of the seat for protracted periods of time. This is important for traffic vigilance as well. Each crew member should have a maximum of three immediate action items to perform from memory. For those who are reluctant to rely on a new crew member, it was noted in the Dehmel that by reducing the number of items, the chance for error is almost eliminated. The phrase "use check list" is better than "when time permits." If the check list is referred to as soon as the three memory items are performed, there is more accuracy and less chance for confusion. The time factor is much shorter than anything in our present system, thus more time available for proper evaluation before the procedure is started. United is changing the check list to an indexed type for quick reference which makes this more plausible.

No One-Man Band

The memory items should be listed in individual columns for each crew member. The Captain must, of course, maintain authority and direction of the entire operation, but this does not mean that he should try to perform as a one-man band. Simplification in phraseology would help. The term "Declutch & Depressurize" is just as descriptive as the twenty or more words now in use. It should be an abbreviated check list and not a detailed instruction manual.

A very important item is to remove the smoke mask from the immediate action steps. In reviewing the results of the CO_2 concentration tests, it appears that the dangers are not as bad as we have been led to believe. There is a serious problem if both banks are discharged before depressurizing, but if the proper procedure is followed without panic, there is a safe time to don the mask before a dangerous concentration of CO_2 exists. Crew coordination, communication and over-all efficiency drops to around 10 per cent in the confusion of donning the mask first. Is it better to put on the mask and forget the important step of discharging CO_2 or carry out an efficient procedure to put out the fire and then don the mask? The Dehmel instructors say that many times the step of discharging CO_2 is completely forgotten using the present procedure! We are presented with a fire hazard, then we get poison to put out the fire, and finally an antidote for the poison that might well be worse than either. The sad part is that several accidents have been a result of false fire warnings! Let's evaluate the problem, realize the dangers involved with CO_2 and then do first things first.

Foolproof Procedures Possible

While it is true that considerable improvement can be expected by revising the procedures without modifying the airplanes, it is readily apparent that with a few modifications the procedures become almost foolproof. For example, the fire-wall shut off valve could be pulled out as it is now and then if CO_2 were required merely turn the same handle and pull it further out. This would eliminate inadvertent discharge of CO_2 before proper selection was made. It also reduces the number of steps. The controls and switches to be actuated for each emergency should be centralized in a common area. For example, if it is necessary to put the mixing valve in port "B" for a cabin heater fire, then the control for this should be in the cockpit and not on the Stewardess Panel at the back door. An improvement in presentation would be the addition of

(Continued on Page 20)

Picture Story:
Fighting Crash Fires With Helicopters

Simulated airplane-crash fire at Kaman Aircraft consists of junk airplane soaked with 400 gallons of aviation gasoline and jet fuel.

A Kaman HOK-1 helicopter carrying pilot and three fire-fighting rescue crewmen hovers while ground crewman attaches fire-fighting equipment to helicopter's external cargo hook. Equipment consists of two Ansul 300-pound-capacity dry chemical tanks, each with 100 feet of hose, and rescue tools.

An aerial fire engine to combat airplane-crash fires and accomplish quick rescue of the occupants is being developed by Kaman Aircraft in cooperation with the Ansul Chemical Company, manufacturers of fire-fighting devices.

The aerial fire engine, which is a Kaman HOK-1 helicopter carrying a pilot, a 3-man fire-fighting team, and Ansul dry chemical fire extinguishers, has successfully demonstrated the time-saving method of rescuing personnel involved in aircraft fires. The helicopter, in addition to transporting the crew and equipment to the scene of the crash, aids in the fire-fighting and rescue by beating down the flames with its powerful rotor downwash.

Speed in getting the men and equipment into action and completing the rescue mission is the outstanding characteristic of the aerial fire engine operation. A series of simulated rescues conducted by Kaman Aircraft have shown that the elapsed time, from the arrival of the helicopter at the scene of the crash, until the dummy "pilot" is rescued from the burning airplane, is consistently under 45 seconds.

In actual operation, aerial fire engine helicopters with rescue crews and equipment on standby at military air bases and civilian airports could quickly reach the crash and go into action. Fire-fighting and rescue operations by helicopters could be carried out even when crashes occur in areas which are inaccessible to ground-operated fire engines and rescue trucks.

The photos on this page show the aerial fire engine in action at Kaman Aircraft during a demonstration for representatives of the U. S. Air Force.

Flying to scene of crash, helicopter hovers and quickly sets fire-fighting equipment on ground. Pilot has just released cargo pick-up cable which can be seen falling away from helicopter's cargo hook.

Helicopter lands near fire-fighting equipment; crewmen disembark and unreel hoses.

As helicopter hovers overhead, using powerful downwash of air from rotors to beat down flames, two firemen go into action with dry chemical extinguishers, opening path through flames for third man who will rescue airplane's "pilot".

With the flames beaten down by helicopter's rotor downwash and subdued by dry chemical, rescue man works to free "pilot" from airplane's cockpit.

Mission is accomplished as rescue man carries "pilot" from crashed airplane. "Pilot" in this case is life-size dummy. Elapsed time of action: less than 45 seconds.

(Continued from Page 18)

a red light in or near the feather button to come on with the fire warning light. All the important fire fighting steps should have a light to prevent actuating the wrong engine controls. We can't expect the Company to rebuild the airplanes, but there are areas for improvement that would not require extensive modifications.

Action Needed Now

The purpose of this article is to point up the ineffective procedures we now have. The solution is another thing. The Company is cooperative and willing to work with us, but the CAA and manufacturer's requirements make changes almost impossible. Perhaps we should work directly with the CAB in an effort to convince them that the procedures may be wrong and not always the pilots. The primary argument I have heard, is that it takes time to do these things, so be patient. In the many years that I have observed and worked on this problem, time has not seemed to help. If anything it gets worse with age. May I suggest that it is time for some progressive thinking and concerted action. The problem exists on all air lines and we will need solid support in our own ranks. Gentlemen, if you decide this is a problem, get behind your representatives with new ideas and we can solve it.

The Pilot-Design Engineer Relationship

Pilots And Engineers Must Recognize Each Other's Competence And Work Together

By William I. Stieglitz

Design Safety Engineer, Republic Aviation Corporation

In the early days of aviation, it was not uncommon for one man to design, build and then fly an airplane. The pilot and engineer was the same man. As airplanes have become more complex, there has been an increasing degree of specialization. More and more engineers are not pilots at all, and even of those who do fly, there are very few who are qualified in modern transport or jet aircraft. The requirements for flying such aircraft are such that, in order to maintain proficiency, flying becomes a full-time job, and not something a man may do in his off-time while working as an engineer. Similarly, the technical knowledge required in the engineering of a modern airplane is such that it is a full-time job to maintain proficiency. Further, the degree of specialization required is so great that not even a professional engineer can hope to be competent in all of the fields involved.

This does not mean that there are not pilots who are competent engineers, or engineers who are qualified pilots; however, such persons represent a small minority. Neither does this mean that an engineer should not, or can not, know anything about flying, or that a pilot should not know anything of engineering. In fact, as will be pointed out later, some such knowledge is almost a necessity in order that each group may understand the other's problems. The statement does mean that neither pilot nor engineer can expect to be an expert in the other's field; that they must recognize each other's competence and work together in order to solve what are, after all, mutual problems. It must be borne in mind that the solution to most problems in aviation is a compromise, and any one of us may see only a small part of the overall picture. There must be cooperation if optimum solutions to our problems are to be found. Too often a completed airplane falls short of the pilot's expectations or has shortcomings from the pilot's viewpoint because of lack of adequate cooperation among pilots, operators, and engineers during the initial design stages.

Cites Three Factors

There have, in the opinion of the author, been three main factors adversely affecting the relationship between the pilot and the design engineer. The first of these is the distance between the cockpit and the drafting room. Few engineers have any direct contact with operating problems. Often, their only direct contact with an airplane occurs when they ride as a passenger on the airlines, when their position is no different than that of any other airline passenger. Most engineers make no effort to talk with the flight crew, and even those who do, find a varying acceptance from pilots. It has been the writer's experience that some pilots are delighted to have an opportunity to talk shop with an engineer, but many of them, when approached, chat casually for a few minutes and go back to the flight deck. Similarly, there are very few pilots who have any direct association with design problems, or an opportunity to spend time in a manufacturer's engineering department.

Actually, there are too many people, operators, company management and sales departments, between the engineer and the pilot. This results in difficulty in the transmission of information. The engineer gets the pilot's problems at third or fourth hand, and the pilot receives the engineer's answer through the same indirect channels. There are, of course, many reasons for this situation; nevertheless, it does impair mutual understanding.

Communication Barriers

Even aside from the difficulties of communication resulting from the foregoing, there is a problem of technical communication. Every branch of technical or scientific specialization tends to develop its own jargon. Therefore with increasing specialization communication becomes more and more difficult. When we talk to a man in a completely unrelated field, we do not expect to understand his technical terminology. The layman does not expect to be able to understand a treatise on medicine. A doctor talking to a patient will put his findings in language the layman will understand, and will not use the same language he would use in discussing the case with another doctor. Similarly, in speaking of technical aviation subjects to a layman, we are careful to avoid technical terms which may not be understood, and to explain such terms as we must use. In talking to anyone in aviation, however, we assume that he will understand our technical terms in the sense in which we use them.

Unfortunately, this is not true. Not only are there terms used in certain fields of specialization which are not used in others, but, more confusing, frequently the same terms are used with an entirely different meaning. Further, there are phrases which are common in everyday speech, but which have a special technical connotation. These are easily misunderstood by the person not familiar with the technical jargon. As one example of such confusion in terms, when in-flight refueling was developed, immediately after the war, someone abbreviated the designation to

IFR. The author once heard a discussion between a powerplant engineer and a pilot in which the former was describing certain conditions which might exist during "an IFR approach." In this case, the entire conversation sounded like something out of "Alice in Wonderland," until it was finally established that the term "IFR" was being used in two different senses.

These difficulties in communication are not insurmountable, provided we recognize their existence, and also recognize our normal tendency to describe technical problems in the terms in which we are used to thinking of them, i.e., in our own jargon.

Need For Knowledge

These language barriers are the basic reason why, as stated previously, there is need for pilots and engineers to have at least a general knowledge of the other's field, and a working familiarity with the vocabulary. In the introduction to "Cybernetics," Wiener states, "if the difficulty of a physiological problem is mathematical in essence, ten physiologists ignorant of mathematics will get precisely as far as one physiologist ignorant of mathematics, and no further. If a physiologist, who knows no mathematics, works together with a mathematician who knows no physiology, the one will be unable to state his problem in terms that the other can manipulate, and the second will be unable to put the answers in any form that the first can understand." The analogy to problems existing between pilots and engineers is readily apparent.

The third problem area affecting the relationship between the pilot and the design engineer is the matter of attitude. For far too many years, many pilots thought of engineers as completely impractical theorists, while many engineers thought of pilots as a group with no technical knowledge as regards airplane design. Such extreme attitudes compounded the difficulty of communication, and of solving what were really mutual problems. Neither attitude was justified. The great majority of engineers are practical men, doing their best to solve extremely difficult problems. The great majority of pilots also spend their lives solving problems—technical problems. While they may not have a theoretical knowledge of airplane design, they do know the design requirements necessary in order for them to solve the operating problems with which they are faced.

What is needed is the recognition of the fact that the technical knowledge of all groups is required to solve our problems. This is primarily a matter

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of good will, of each accepting the other as competent in his own field, and accordingly making every effort to understand the other's viewpoint. On both sides, the important thing is a willingness to attempt to understand; on the part of the engineer to know *why* a pilot objects to something, or wants something in a certain way; and on the part of the pilot to know *why* the engineer designed something the way he did.

Design Field

In no area is this more important than in the areas of design in which human engineering is involved. There have been many difficulties in the way of adoption of human engineering data in design, and too great a lag between research in the field and incorporation of the findings in airplanes. There are many reasons for this, not the least of which has been the communication problem between the human engineer and the design engineer. On the other hand, many things which have appeared in cockpits on the basis of sound human engineering data have been rejected by pilots because of lack of understanding of why the change was made.

There is a basic human resistance to change; we tend to like and to want, and to stay with, the things we are used to. Training, experience and habit often permit us to use effectively things which are not, in and of themselves, either optimum or efficient. Changing to something new means a relearning process. There have been cases of psychological tests on instruments in which the pilots, on their initial tests, did better with the existing display than with the new presentation, although non-flying personnel showed markedly superior performance with the new display. Obviously, in this case there was a habit interference on the part of the pilot, but the fact still remains that the revised display was more "natural," and would therefore, with adequate training and experience on the part of the pilots, result in more efficient operation, with less fatigue. Yet changes of this sort have frequently been opposed by pilots, largely because of lack of knowledge and understanding of the basis for the change. This, in many cases, may not have been the fault of the pilot, but rather have resulted from the fact that the pilot had not been given the background.

Summary

It has been the purpose of this paper to point out what the author considers problem areas in the relationship between the pilot and the design engineer

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which are adversely affecting our progress toward air safety. There are no simple, ready-made solutions to these problems. Progress is definitely being made. Meetings such as this, with design engineers and other representatives of industry taking part in a pilots' meeting; presentation of papers by members of this organization to engineering meetings, such as that of the Institute of the Aeronautical Sciences a few months ago; the free exchange of opinions among pilots and engineers at meetings such as the annual seminar of the Flight Safety Foundation; all promote better understanding, and are steps toward solving these problems. Basically, however, it is a matter of attitude, of a readiness to cooperate, and a desire to work together.

Navigation . . .

(Continued from Page 4)

ment with respect to north, and in the local horizontal. These corrections are required for two reasons: first, the gyros are sensitive both to the rotation of the earth itself and to the vehicle's *angular* travel over the earth's surface. The equivalents of these known *rotational* quantities are computed and introduced as compensations to keep the platform level and properly directed. Second, the accelerometer outputs contain quantities representing accelerations produced as a function of the earth's rotation; these *accelerations* are also computable values for which compensations are made.

The computers which determine present position by operating on acceleration signals and by generating compensations, are also capable, with little additional gear, of developing other useful information. The *course* the aircraft should take to get to the destination, the aircraft's *heading*, the *distance to destination*, etc., are available from such systems, both as visible displays and as signals to autopilots for automatic flight control purposes.

Each one of the elements of inertial navigation systems—the accelerometers and gyros, the transducer devices which convert angular motion to electrical signals, the small meters and the computer components—must be highly sensitive, well-balanced, fast-responding and very accurate, in order to perform adequately the sensing, computing and correcting function required. Only in recent years have instruments with the required precision been developed to the point where such a method of navigation has become practical. It is probable that the next few years will show increasing use of inertial systems for aerial navigation.

Do Not Replace Pilots

These navigational systems can fallaciously appear to add up to automatic navigation of long overseas flights in jet transports. Should the pilot who is assigned to navigate our overseas flights be eliminated? *No*—this writer will venture to say. These black boxes are merely navigational aids, their chief value being to expedite and add precision to our navigational procedures (and airway traffic control) in high speed aircraft, wherein our present leisurely methods will not always be tolerable.

Along with the black boxes we, as pilots, must maintain a high level navigational capability, continuously checking against the performance of the electronic equipment. This duty, with the attendant paperwork, must not be thrust into the pilots' cockpit which will, at times, be completely busy with other vital matters.

(Acknowledgements to Mr. David Balber of the Kearfott Co., manufacturers of Inertial equipment, and to the General Precision Laboratories, manufacturers of Doppler equipment.—C. B.)

A System For Tracking With The ADF, *by Capt. O. B. Bivens, in the May* Air Line Pilot *was printed through the courtesy of* Skyways *magazine.*

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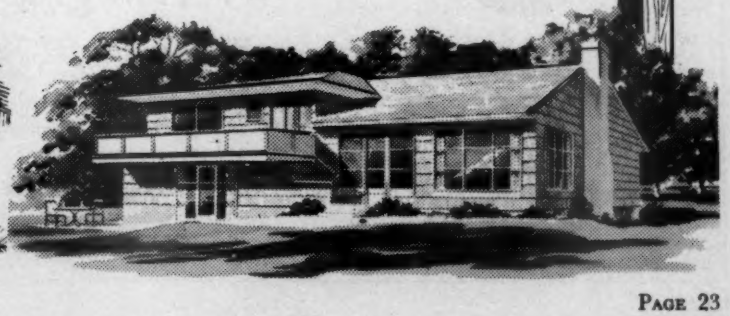

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2. We have received so many requests for coverage from co-pilots who are not yet eligible to join, we are changing the master policy as follows: "A co-pilot will be eligible to join without a physical examination any time after completing one year of service and before completing two years and two months".

3. Co-pilots who are under 40 years of age but did not join prior to two years and two months service may now join by taking a physical examination from a C. A. A. examiner in connection with a C. A. A. Class 1 physical. The examination forms will be supplied on request by Aviation Insurance Agency, Inc.

4. This is the only coverage for an airline pilot that will pay $25,000. cash, tax free, if he is permanently prevented from flying for his airline as a captain, for physical reasons, regardless of his C. A. A. physical status. Premium is collected by payroll deduction.

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